Three-Dimensional Magnetic Field-Line Topology in the Outer Heliosphere

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Voyagers 1 and 2 (V1 and V2) are rapidly approaching the interface between the solar wind and the plasma in the local interstellar medium. The most accurate estimates today place this encounter as taking place starting almost immediately and lasting until around the year 2010.[1] After that time, the two spacecraft will be entirely in the local instellar medium. During the encounter, Voyagers 1 and 2 will be crossing a region of space known as the heliosheath—a region still within the heliosphere (its volume dominated by solar wind plasma).

The heliosheath solar wind has been slowed as it passes through the "termination shock" and has turned to begin flowing parallel to the wind in the local interstellar medium and down the heliotail. The interaction between the interstellar wind and the solar wind is illustrated in figure 22

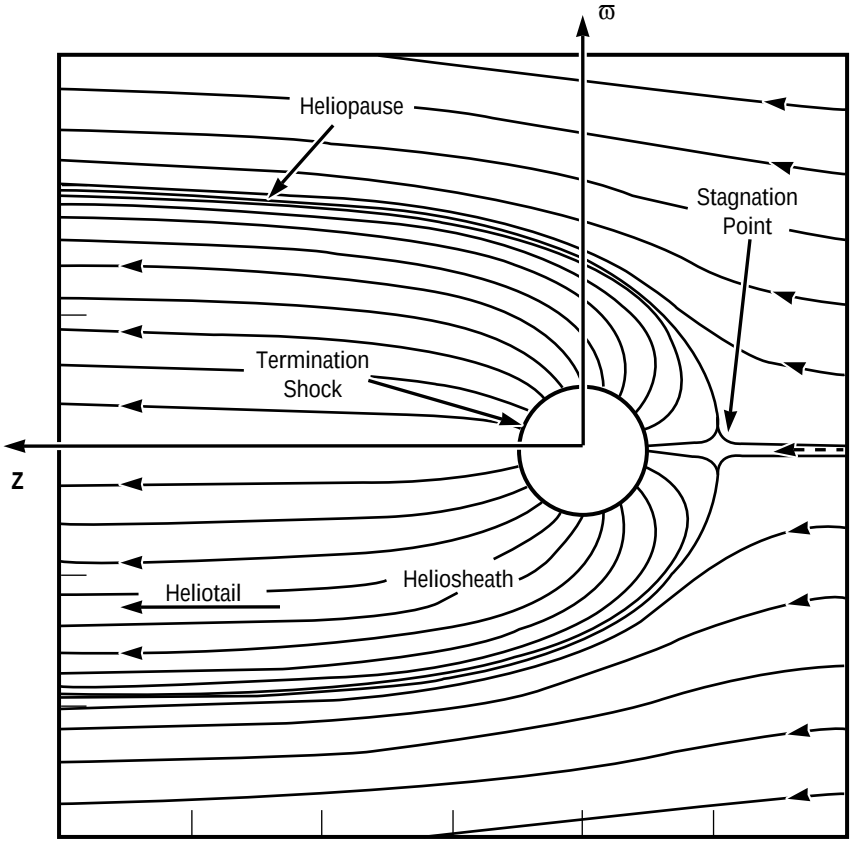

FIGURE 22.—Interaction between the local interstellar medium wind and the solar wind.

(labels indicate the various volumes just described); Voyagers 1 and 2 are traveling in the upstream direction, to the right. To characterize the scale in this figure, the radius of the termination shock is probably about 75 astronomical units (one unit is the average distance from the Sun to the Earth). All of the planets lie inside 50 astronomical units and inside the present locations of Voyagers 1 and 2.

While in the heliosheath, the Voyagers will perform several measurements. One of the most important of these is the determination of the topology of the magnetic field lines. Because the spacecraft will only measure the vector magnetic field direction and amplitude along the path of their orbits, the interpretation of the results will depend on having a model in hand for comparison. Over the past year, MSFC researchers have completed the first and only such model, successfully computing the topology of magnetic field lines in the heliosheath and the imprint of the solar magnetic cycle on this topology.[2] Figure 23 provides the topology of the magnetic field lines. (The sphere in the figure is the termination shock shown in fig. 22.) Several sample field lines in the northern hemisphere have been selected for the purpose of this illustration, and only some of the physical parameters have been chosen to illustrate the overall topology without unnecessary complexity. The varying of the interplanetary spiral magnetic field (an Archimedian spiral) out through the termination shock and into the heliosheath had not been previously visualized. The looping spirals are advected either north or south, depending on whether they lie in the northern or southern hemisphere of the Sun (fig. 23). Only loops in the

northern hemisphere are shown—with a mirror reflection of the loops existing in the southern hemisphere. This splitting is a consequence of the interaction between the solar wind and the local interstellar medium being a type of stagnation point flow (fig. 22), with the splitting occurring in the vicinity of the stagnation point. As the magnetic loops are carried back into the heliotail, they form two lobes in the northern and southern portions of the heliotail.

Model calculation (illustrated in fig. 23), when compared with the observational results from Voyagers 1 and 2 as they cross the upstream heliosheath, will be used to determine the appropriate physical parameters for the heliosphere—the interstellar medium system. The magnetic field model itself will then become a quantitative tool for evaluating the entry of galactic cosmic rays into the heliosphere.

[1]Gurnett, D.A.; Kurth, W.S.; Allendorf, S.C.; and Poynter, R.L. 1993. Radio Emission From the Heliopause Triggered by an Interplanetary Shock. *Science*, 262:199–203.

[2]Nerney, S.F.; Suess, S.T.; and Schmahl, E.J. 1995. Flow Downstream of the Heliospheric Terminal Shock: Magnetic Field-Line Topology and Solar Cycle Imprint. *Journal of Geophysical Resources*, 100:A3, 3,463–71.

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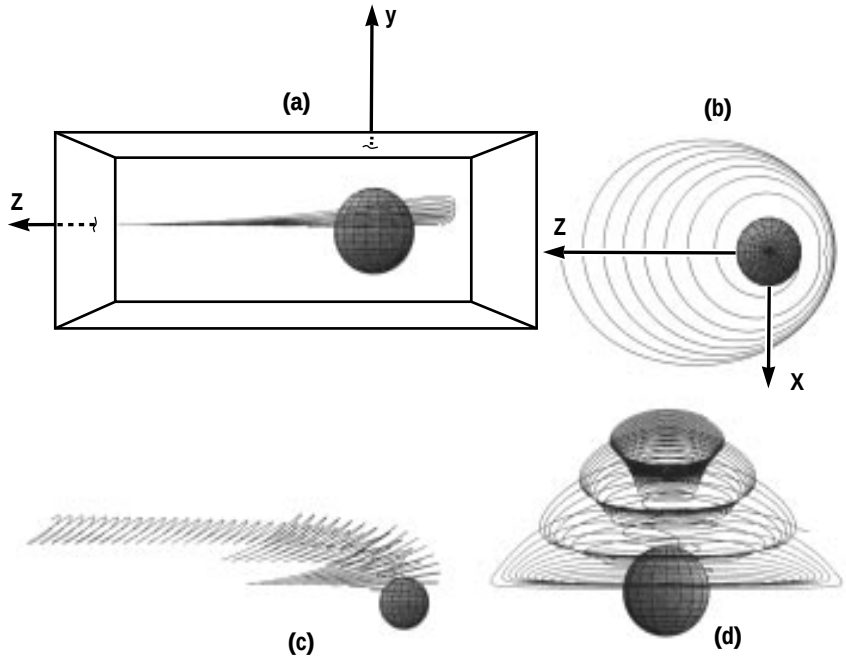

FIGURE 23.—Topology of magnetic field lines.